JOURNAL

JANUARY, 1933

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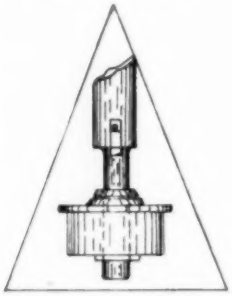

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A. S. T. E. Journal

Published by the American Society of Tool Engineers

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Detroit, Michigan

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Owing to the nature of the American Society of Tool Engineers organization, it cannot be responsible for statements appearing in the Journal either as advertisements or in papers presented at its meetings or the discussions of such papers printed herein.

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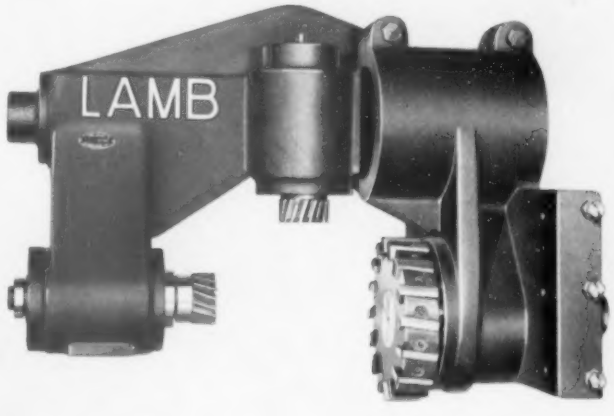

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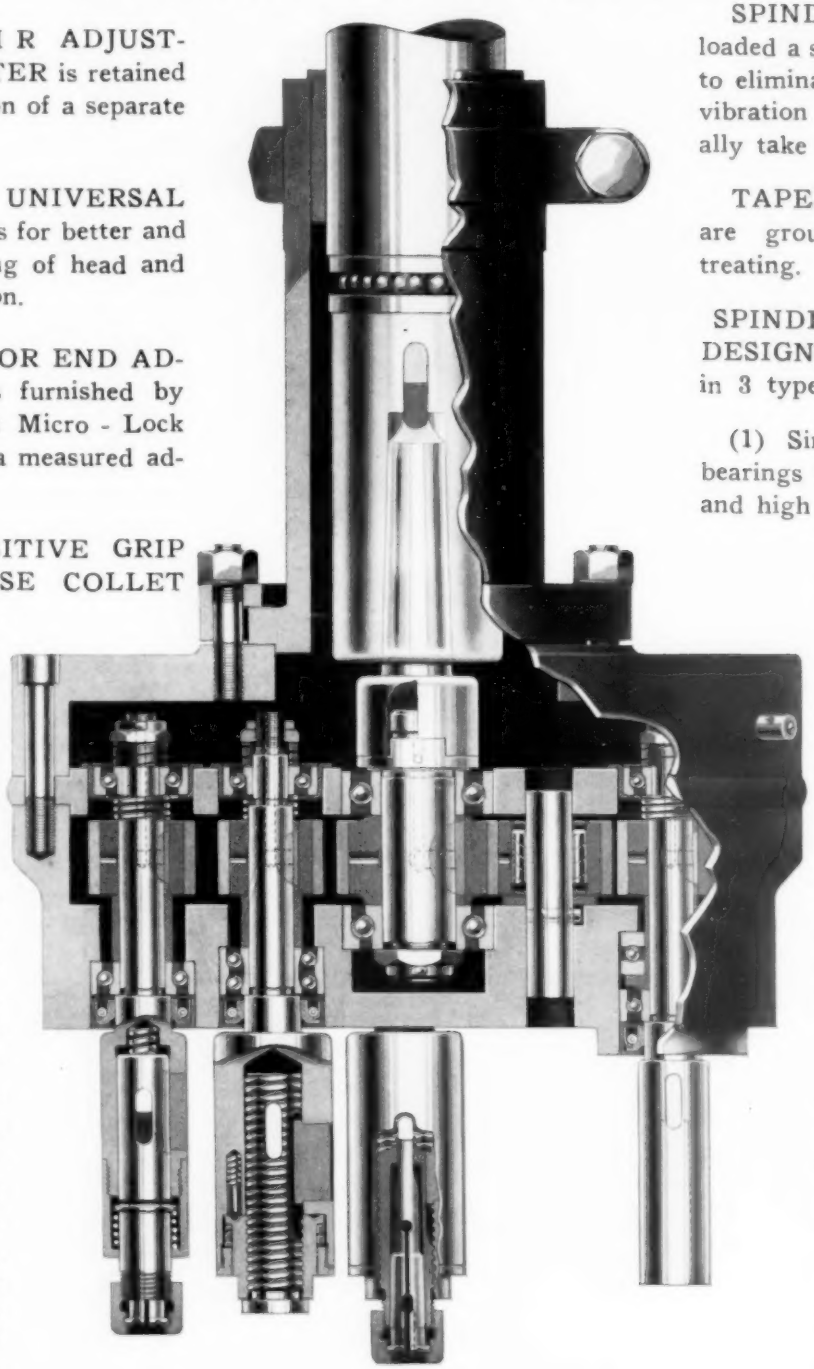

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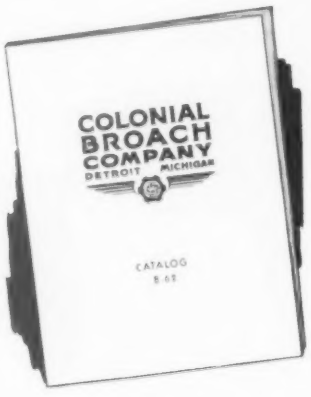

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A copy of this Catalog will be sent to mechanical executives interested in broaching. Write for your copy today.

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1933?

To the members of the American Society of Tool Engineers we extend wishes for a happy year in 1933. We almost said happy and prosperous, but realized that the word prosperous in the case would be superfluous. To be happy during 1933 means to be prosperous, not necessarily in material things, for happiness is prosperity. A happy man is a wealthy man even if he has not a dime.

What have we a right to expect of 1933? We can not be unmindful of the fact that 1933 is not 1929. The standards of 1933 will not be the same standards we used in 1929. During the years of "prosperity" we learned to consider wealth as being represented largely by certain highly engraved pieces of paper called stocks and bonds. Our wealth may have consisted of a sheet of paper representing 100 shares of General Motors Stock. Theoretically this might mean that we individually owned certain tools used by the General Motors Corporation in the manufacture of automobiles, or a certain portion of some building used by them, but the ownership of this property meant nothing to us unless the General Motors Corporation could use it along with the rest of their holding to make a profit. We could not use our portion of their holdings as represented by our stock certificate in any way to benefit ourselves individually. We could not eat it, drink it, or wear it, and it wouldn't go far in keeping us warm. Was this real wealth? Unless General Motors Corporation made a profit for us we did not have any wealth for the paper must certainly be valued according to its ability to earn or its future prospects for earning

It might be well for us to re-inventory our possessions and place a corrected value on holdings. Home, family, children, relatives, friends, and associates are valuable to a greater degree than we realize. Pehaps our material holdings are worth less than we realize. Let's stop looking for that corner, around which business is to turn, and adjust ourselves to the fact that we are entering a new era. We are all here, we produce plenty of food, clothing, heat, and products of all kinds. There is no shortage of anything except dollars upon which we have placed too great importance. We are not going to stand still. We will develope our resources and produce still more things to add to our ease, comfort, and happiness.

The American people are too aggressive to be licked by a condition which apparently consists in a lack of a proper distribution. The change is so great that it takes us some time to understand it sufficiently to take the proper steps to correct it. But it will be corrected.

We have family, friends, and associates, and we still have the ability to create. Thus we have wealth. A proper valuation of these should produce a mental state which would enable us to enjoy these things and be happy.

WE HOPE

Thursday,
January 12, 1933,
at
Detroit Leland Hotel,
Main Ball Room.

Dinner, 6:30 P. M.
$1.00 per plate.
Meeting at 8 P. M.
Members not wishing to attend the dinner are urged to attend the meeting at 8 P. M.

SPEAKERS

Mr. Elmer G. Koch,
Industrial Sales Division,
Bausch and Lomb Optical Company,
Rochester, New York.

—Subject—

"THE MANUFACTURE OF OPTICAL INSTRUMENTS AND THEIR APPLICATION TO THE MACHINE INDUSTRY."

Mr. Elmer Koch has had a wide and varied experience in the machine tool industry as well as having been connected with the Bausch and Lomb Optical Company for the past twenty years.

For six years Mr. Koch was the head of the Gauge Inspection Department of Bausch and Lomb, and it was here that an important part of the initial development of optical inspection instruments took place.

From that department Mr. Koch went to the Sales Department, where he has been associated for the past nine years. Here he has been in constant contact with the inspection problems of metal fabricators, and has become an authority on the application of optical instruments to the solution of these problems.

Mr. J. Charles Mottashed,
Personnel Manager,
Hudson Motor Car Company,
Detroit, Michigan.

—Subject—

"TOOL ENGINEERS—ARE THEY PEOPLE?"

HORIZONTAL AUTOMOBILE ENGINES

Announcement has recently been made by the White Company of a new engine departing radically from the customary design. Designed for city service motor coach use, this twelve-cylinder horizontally opposed 225 horse-power engine has an overall height of but sixteen inches which permits its being mounted under the floor of the coach, thus providing room for forty-four seated and fifty-six standing passengers. The new buses are of all steel construction and are claimed to possess the "lowest center of gravity of any motor coach."

A chemical mixed with dyes is now being used in the manufacture of stockings which, although odorless and harmless to the wearer, is deadly to the mosquito.

Good humor and gaiety are symptoms of a balanced mind. However, the balanced mind often functions in a non-understandable manner. While we expect a crowd to laugh at Charlie Chaplin, we note that it rarely laughs at a political speech.

You might even expect it to laugh a little at itself on Election Day. But it rarely does.

Mrs. Dee: Did you say you thought I looked better lately?

Mrs. Cee: Not exactly. I said you looked more like yourself.

Two line philosophy: If I got to have trouble, I'd rather have a black cat cross my path than a Mack truck.

MEMBERSHIP DRIVE

Congratulations to Messrs. F. L. Hoffman, Walter F. Wagner, Kenneth C. Snell, Wm. C. Maier, and O. B. Jones! They were the class of the field in the membership drive race just completed. The winning team will be the guests of the other teams at the dinner meeting Thursday, January 12, 1933, at the Detroit Leland Hotel. Again, accept our felicitations, Team No. 2. And allow us to extend a word of appreciation for the efforts of the teams, who, though they did not win the laurels, did valuable work to the Society in recruiting new members.

1. C. B. SMITH, *Captain*
   E. M. BEYMA
   DWILLARD J. DAVIS
   ROBT. W. FRYE
   ED. SHUBACK

2. F. L. HOFFMAN, *Captain*
   WALTER F. WAGNER
   KENNETH C. SNELL
   WM. C. MAIER
   O. B. JONES

3. WM. (BILL) GRAY, *Captain*
   JOE DILLON
   B. BUSWINKA
   T. POUTTU
   J. GIERN

4. E. C. MacKenzie, *Captain*
   C. THIEDE
   JOS. P. MILLER
   KARL W. LEGG
   HERBERT B. NORQUIST

5. GEO. E. LEGGATT, *Captain*
   LEE DIAMOND
   H. C. BEHM
   W. L. NEWTON
   CHARLES R. STAUB

6. EDWIN LANG, *Captain*
   B. C. FLEMMING
   LEROY ANDERSON
   ALFRED S. CUMMINGS
   CARL J. MARX

7. K. F. RANGER, *Captain*
   H. GILLER
   SAM READ
   ART FELL
   A. SUBIA

8. JOE SLAVIK, *Captain*
   GEO. BOLAND
   FRANK M. GERTISER
   D. W. PATTERSON
   R. S. SPENCER

9. A. H. HOFFMAN, *Captain*
   E. A. BRANCHOFSKY
   E. A. RUTT
   C. E. TEFFT
   W. L. WILLSON

10. WM. PETERSON, *Captain*
    H. S. BRANDT
    J. O. GANGLER
    F. H. HARTLEP
    C. J. OXFORD

EDITORIAL PAGE

IS PURE SCIENCE PRACTICAL?

There exists an unfortunate tendency on the part of many practical scientists and near-scientists, such as engineers, tool designers, and mechanics, to look upon pure scientific research either as a harmless but useless diversion for cranks and idle dreamers, or, worse still, a positive waste of time that might be employed in more useful work. Such hard and practical persons dismiss the latest discoveries and theories in science with a supercilious shrug of the shoulders. "The wave theory of matter, the curvature of space, the splitting of the atom, the cosmic rays—that stuff may be all right, but it has no practical applications," says Mr. Hard-boiled Tool Engineer. "I am more of a practical scientist than Einstein and some of those birds, because what I do increases production, reduces manufacturing costs, and increases the wealth of the world. In what way does the work of Einstein improve our standard of living, or increase our happiness and well-being?"

Perhaps it might prove illuminating to these self-styled "practical scientists" to point out to them the part that pure scientific experimentation, undertaken for its own sake alone with nothing practical in view, has played in making our world what it is today.

It may sound startling, but it is nevertheless true, that if it were not for the work of the astronomers from earliest times up to the eighteenth century, modern machine and production work would be impossible. What would the tool engineer, or any type of engineer for that matter, do without trigonometry? Yet it was the early astronomers who developed that branch of mathematics in connection with their measurements of terrestrial and solar distances. It was not until the time of the great mathematician Euler that trigonometry became a separate study distinct from its parent, astronomy.

Our present age of machinery, steam, and electrical power, and hence mass production, was rendered possible only through two accidental theoretical discoveries. Papin, an assistant to the great scientist, Huygens, like his master, was interested in vacuums. To get a better vacuum he hit upon the idea of a piston moving in a cylinder. James Watt and some of his unsung predecessors seized upon this germ, a piston and a cylinder, and perfected the steam engine, which ushered in the Industrial Revolution. Thus Papin, conducting a disinterested, pure scientific research into the subject of vacuums, was one of the prime movers of the machine age. When Faraday first discovered that rotating a copper disc between the poles of a magnet generated an electric current, he was warmly derided by a nobleman friend of his for wasting his time with such idle playthings. Yet, out of that vain chimera of a pure scientist has come our era of electricity and giant power. For Faraday had discovered the principle of the dynamo.

When Madame Curie discovered and isolated radium, inaugurating that series of researches that has revolutionized our conceptions of matter and energy, it is doubtful if anyone expected any practical consequences to flow from the discovery. Indeed, at present, these new fields of research into radioactivity, the ultimate nature of matter, and the disintegration of the once supposedly permanent elements have yielded little in the way of practical fruits, outside of the use of radium in medicine. But recent progress in these fields promises—or shall we say threatens—practical applications, which may prove the greatest blessing or the greatest curse yet falling to the lot of mankind, depending upon the wisdom and unselfishness with which these applications will be introduced and utilized. The industrial use of vast and unlimited stores of intra-atomic energy in the not very distant future may mean universal well-being and freedom from drudgery for every man, woman, and child on this planet; but, in view of human nature as it is today, there is grave danger that the benefits of the new sources of energy will fall into the hands of a few unscrupulous exploiters and be used to enslave the many. The transmutation of the elements has been seen to take place in nature when radium disintegrates into lead and helium. It is well within the bounds of possibility that the dream of the medieval alchemists may yet come true and "base" lead be transmuted into gold. Should this happen, it is diverting to imagine the panic that would seize our respectable and conservative bankers and politicians when artificial production depreciates the value of gold almost to nothing and undermines the "integrity of our dollar."

Another example of a pure scientific discovery later having unsuspected practical applications is the discovery of the gas helium. When this element was discovered in the atmosphere of the sun, through spectrum analysis, in 1868, twenty-six years before it was found on this earth, no doubt many of our forbears said, "Interesting, but of what use is it?" But today we find helium being used more and more as a substitute for hydrogen in filling the gas bags of lighter-than-air flying machines.

Therefore, you practical men, scoff not at the theory of relativity, the fourth dimension, or even the most ridiculous piece of game shot down by the philosopher on a will-o'-the-wisp hunt, for who can foresee what new marvels, what transformations of our earth and our way of living, may grow out of today's most vain speculations?

LAST MEETING

Members who were present at the December meeting were privileged to hear Mr. J. MUSSER MILLER of the Technical Department of the STANDARD OIL COMPANY tell the story of Gasoline, beginning with its discovery and leading up to the present day.

Few of us realize the magnitude of the oil industry, and we were surprised to learn of the enormous holdings of the oil companies. This industry has developed its own transportation system, including the various pipe lines. There are over 110,000 miles of pipe line in use conveying oil throughout the country. This compares favorably with the estimated 150,000 miles of main line railroads in the country.

Oil is pumped through the pipe lines at pressures up to 600 pounds per square inch by pumping stations located up to 60 miles apart. Some of these lines originating in the Texas and Oklahoma oil fields carry to both the East and West sea coast and to the Gulf coast. Storage tanks up to 3,000,000 gallons capacity are used at the fields and in other locations.

Distillation is the principal means of obtaining gasoline from crude oil, and the cracking process is used to obtain additional gasoline from the crude oil beyond what is possible by the distillation method. Most present day gasolines are "washed" by the acid process to remove impurities, principally sulphur, which would be detrimental to the car in which they are used. Great care and many tests assure the production of very even qualities.

Vapor Lock

Vapor lock was described by Mr. Miller as being the result of gasoline turning from a liquid to a gas in the carburetor and lines. This condition occurs on hot days when heat from the motor and atmosphere changes the gasoline from a liquid to a gaseous state. The gasoline expands many times its volume when turning to gas, and, naturally, insufficient volume of gas passes through lines and openings designed for liquid, with the result that the motor is "starved." Vapor lock results from bad car design in addition to the quality of gas used.

Octane Rating

The Octane rating of a gasoline tells very little of its quality or purity. This rating applies only to the anti-knock qualities of the gas. The Octane rating of a gasoline is obtained by comparing its anti-knock qualities with a known anti-knock substance. This test is made in a special engine with apparatus arranged so that conditions can be controlled closely for identical runs. If, for instance, a gasoline compares in anti-knock quality with a substance containing 72 per cent Octane, it is known as 72 Octane gas.

Taxes

The gasoline industry has been loaded with more than a normal tax load. In the opinion of many this industry has been saddled with more than its fair burden of taxes. A large number of states apply a state gas tax varying from two to five cents per gallon. The Federal government taxes gasoline one cent per gallon and oil four cents per gallon. The industry pays, state, county, and municipal taxes on service stations, refineries, storage fields, pipe lines, pumping stations, and real estate. It pays personal taxes on trucks, cars, service station equipment, containers, machinery, and other personal property. It pays weight taxes in the form of licenses for all delivery trucks, trailers, and cars; license taxes to do business; sign taxes for signs; and income taxes if a profit is realized after the foregoing list of taxes is paid. With gasoline selling retail at 12½ cents per gallon the state tax of two to five cents per gallon plus the federal tax of one cent per gallon plus the weight tax, the real estate tax, the personal tax, and the income tax, must cause them to operate on a rather small margin, considering the distance the product is transported and the service given.

The Motion Picture

Mr. Miller showed two reels of film along with the story gasoline, and the chart arrangement of the many processes made the picture a very interesting one. It showed the movement of gasoline from its crude oil state from the well to its delivery into automobiles from the service station. Each process was charted to show what takes place in the equipment used at various places. The method of testing was shown and described, and we believe all present enjoyed the subject immensely.

THE FACTORY WITHOUT EMPLOYEES

The paper, "The Tool Engineer's Place in Mass Production," which was presented at the November meeting by Mr. O. B. Jones, apparently caused some thinking on the subject, judging by the remarks from various members.

No doubt many members disagree with Mr. Jones on some points brought out in the paper, and it would be very interesting to print the opinions of other members on the same subject.

At the December meeting, Mr. Spencer, of Detroit Boring Bar Company, discussed one point in particular which referred to Mr. Jones' "ideal factory." He did not think the factory without men, as described by Mr. Jones, was meant literally. In view of present unemployment conditions, it would

seem to be a step in the wrong direction to further the development of machines, equipment, and processes to the extent of being able to manufacture an article in a factory which would be fully automatic and required no workers except the maintenance division, the stock division, and the organization proper.

In reply to this discussion, Mr. Jones went further in describing his meaning. He brought out the fact that we already have machines which are entirely automatic, with the rough stock being fed into a hopper and the finished stock removed in containers, as is done with certain types of screw product machines.

Only a few meetings ago, we were privileged to view a film showing the operation of certain loading devices as developed by the Seneca Falls Machine Company, and saw how stock was advanced from one machine to the next and finally to a conveyor from the last operation. We learned that these automatic handling devices could be applied to a large number of machines as well as on the small group we saw. As we stop and consider the development which has taken place in the past few years in machinery, handling equipment and processes, it is easier to concede that a factory designed to be fully automatic may not be an impossibility in the next few years.

The effect of this development on the labor situation did not seem dangerous to Mr. Jones, but rather he saw that good could come of it. Originally, a man's work was rated on the basis of how much work a man could do in a day of purely physical labor. (Main strength and awkwardness). One man power equals approximately 1/8 of one horse power. Our engineers have developed the use of some of the earth's resources, such as electricity, fossil oils, and steam, so that it is possible for two or three men to produce 20 to 30 thousand horse power if given a modern power house to operate. Rarely does a man in these days produce only one man power. It is estimated that less than 5 per cent of all power used in industry today is actual muscular labor or man power. The argument against development because of its effect upon unemployment seems unsound.

If it is advisable to stop development to prevent further reducing of the demand for workers, why not go further and consider doing away with some of our modern equipment and thus increase the demand for muscular labor? Why not go still further and do away with automobiles and street cars, and walk to work? Think of the help this condition would be to the shoe industry! Demolish the typewriter. Wouldn't this be a boon to the stenographers looking for jobs? Without the milling machine we could use plenty of men with files. In considering this phase of the situation, we admit that we are thinking of the other fellow using the file, for we know we would rather press a button.

Scientific development will not stop. Rather it is accelerated by conditions such as those at present. We may approach closer to the time when a man can, by skillfully manipulating a few levers, produce sufficient in one hour a day to provide for his and his family's needs. He will have more time for physical, mental, and spiritual development, leading, perhaps, to a happier and a fuller life.

The OK Tool Company, Incorporated, Shelton, Connecticut, announces the publication of a new circular entitled "OK Combination Tools."

This circular illustrates graphically the wide application and design of OK Cutter Blades as applied to combination tools for core drilling, reaming, boring, counterboring, facing, hollow milling, or trepanning.

The OK Tool Company will be pleased to send copies of the circular on request.

A business man in a small town recently called upon his local banker to request a loan.

The banker was not in a loaning frame of mind however and absolutely refused. But the business man was not discouraged and pleaded long and earnestly until finally from sheer exhaustion the banker made him the following proposition.

"For years I have had a glass eye. I paid a lot of money for it and take great pride in the fact that no one has ever discovered it. Now then if you can look me in the eyes and point out the artificial one I'll be glad to loan you the money."

The B.M. took a good look and then said "The right one is the artificial eye."

The right one it was, but because no one had ever discovered it before and because the merchant had picked it so easily, the banker was curious to know how he had done it.

"That's easy," said the B.M., "it has a more human look than the other."

Wife (at head of stairs, 2 A.M.): "Is that you Ray?"

Ray: "Well, who were you expecting?"

"And is there any instrument that you play?" asked the woman who was pressing guests into service to provide entertainment.

"Not away from home," Jenkins replied.

"Oh, that's queer. What do you play at home?"

"Second fiddle."

At the breakfast table one morning I was reading in the paper where a couple in Colorado were buried in a snowdrift for eighteen hours, and I said to the waitress: "How would you like to be buried for eighteen hours in a snowdrift with your sweetie?" And all she said was: "Say, if me and my sweetie was buried in a snowdrift, we'd be swimmin' in twenty minutes."

CHAPTERS

The Constitution and By-Laws Committee have held several meetings in an effort to properly provide means of organizing and controlling chapters of the ASTE, independently governed, in various cities throughout the United States. While this work has not been completed, the following regulations have been tentatively adopted as covering generally the requirements of individuals or groups who would attempt to sponsor a local chapter.

No. 1—Groups of 25 members sanctioned by the Board of Directors may conduct the affairs of the society pertaining to that group at any time and place they may elect.

No. 2—This group shall be known as a Chapter and will be given the name of the city in which they conduct their meetings.

No. 3—The Chapter is to be governed locally by the following officers selected by the members of the chapter subject to the approval of the Board of Directors; Meetings Chairman, Vice-Chairman, Assistant Secretary, and Assistant Treasurer.

No. 4—It shall be the duty of the Meetings Chairman to preside at all meetings of the Chapter. He may appoint any special or standing committees to assist him in carrying on the business of the Chapter.

No. 5—It shall be the duty of the Assistant Secretary to record the minutes and happenings of all meetings and forward them as soon as possible to the Secretary. The Assistant Secretary shall also carry on any other correspondence pertaining to the business of the Chapter.

No. 6—It shall be the duty of the Assistant Treasurer to have custody and keep accounts of all money, funds, and property; he shall without delay, send to the treasurer, moneys, or property accrued by the Chapter. He shall request appropriations and properly handle disbursements from the Society for the conduction of the Chapter's business. He shall perform in addition such other duties as may be delegated to him by the Treasurer. He shall furnish a bond for the faithful performance of his duties at such amount as the Treasurer may require.

No. 7—The Vice-Chairman shall preside in the absence of the Chairman and perform any other special duties delegated to him by the Chairman.

No. 8—These officers shall perform the duties legally or customarily attached to their respective offices and shall conduct their meetings in accordance with the care and regard for the welfare of the society exercised by professional men in similar circumstances.

The work of this Committee is continuing and further details will be provided as fast as they are prepared.

A. M. Sargent, Secy.

NEWS NOTES OF THE INDUSTRY

As December production reached the half-way mark it looked reasonably certain that motor vehicle production is going to exceed that of December, 1931, which was 123,973 units. Present estimates are that December, 1932, production will show a minimum of 135,000 vehicle units. If this estimate proves to be accurate, December will be the first month in 1932 that has shown a greater production total than the corresponding month in 1931.

The adoption of electro-plated pistons in all Studebaker truck engines and the application of B-K vacuum brake boosters as standard equipment on its model S-4, 1¼ to 2½ ton truck is announced by the Studebaker Corporation.

Monsieur Andre DuBonnet has arrived in New York to exhibit his new springless chassis at the New York Automobile Show. Monsieur DuBonnet has been working on his invention for the past five years and presented it for the first time at the Paris Automobile Salon last October.

A larger, roomier and mechanically refined Terraplane 6 will be announced at the time of the New York Automobile Show, according to the Hudson Motor Car Company. In addition there will be a return of the Hudson Super Six. Improvements will also be made in the Hudson Eight, which will be continued.

Present activity among the vehicle manufacturing plants in the Detroit area has been reflected in parts factories' schedules in the area. The steel industry has also felt this increase. Chevrolet now has bids in hand for its steel requirements for the first quarter of 1933, consisting principally of sheet and strip. Chrysler has been placing parts orders, while Hudson has spent approximately $12,000,000 on materials and parts for its new lines.

Index figures just released by the Detroit Board of Commerce show that employment on December 15 was 44.2, comparing with 39.3 on November 30. While this is an encouraging sign, employment in Detroit is still below 1931 levels, the index on December 15 last year being 60.7.

Validity of a patent said to cover every known process of chromium plating is challenged in a petition just filed in the U. S. Supreme Court by the International Silver Company.

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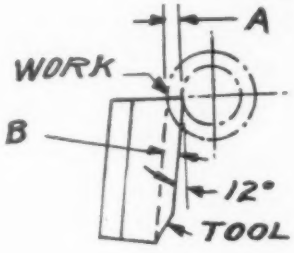

CORRECTED DEPTHS OF FORM TOOLS SET AT 12° ANGLE

NOTE—

FOR FORM TOOLS SET AT OTHER ANGLES MULTIPLY COSINE OF SAID ANGLE BY DEPTH OF CUT ON WORK TO OBTAIN CORRECTED TOOL DEPTH "B."

.000 TO .230

A	B	A	B	A	B	A	B	A	B
.001	.0010	.047	.0460	.093	.0910	.139	.1360	.185	.1810
.002	.0020	.048	.0470	.094	.0920	.140	.1370	.186	.1819
.003	.0029	.049	.0479	.095	.0929	.141	.1379	.187	.1829
.004	.0039	.050	.0489	.096	.0939	.142	.1389	.188	.1839
.005	.0049	.051	.0499	.097	.0949	.143	.1399	.189	.1849
.006	.0059	.052	.0509	.098	.0959	.144	.1409	.190	.1859
.007	.0069	.053	.0518	.099	.0968	.145	.1418	.191	.1868
.008	.0078	.054	.0528	.100	.0978	.146	.1428	.192	.1878
.009	.0088	.055	.0538	.101	.0988	.147	.1438	.193	.1888
.010	.0098	.056	.0548	.102	.0998	.148	.1448	.194	.1898
.011	.0108	.057	.0558	.103	.1008	.149	.1458	.195	.1907
.012	.0117	.058	.0567	.104	.1017	.150	.1467	.196	.1917
.013	.0127	.059	.0577	.105	.1027	.151	.1477	.197	.1927
.014	.0137	.060	.0587	.106	.1037	.152	.1487	.198	.1937
.015	.0147	.061	.0597	.107	.1047	.153	.1497	.199	.1947
.016	.0157	.062	.0607	.108	.1056	.154	.1506	.200	.1956
.017	.0166	.063	.0616	.109	.1066	.155	.1516	.201	.1966
.018	.0176	.064	.0626	.110	.1076	.156	.1526	.202	.1976
.019	.0186	.065	.0636	.111	.1086	.157	.1536	.203	.1986
.020	.0196	.066	.0646	.112	.1096	.158	.1546	.204	.1995
.021	.0205	.067	.0655	.113	.1105	.159	.1555	.205	.2005
.022	.0215	.068	.0665	.114	.1115	.160	.1565	.206	.2015
.023	.0225	.069	.0675	.115	.1125	.161	.1575	.207	.2025
.024	.0235	.070	.9685	.116	.1135	.162	.1585	.208	.2035
.025	.0245	.071	.0695	.117	.1145	.163	.1594	.209	.2044
.026	.0254	.072	.0704	.118	.1154	.164	.1604	.210	.2054
.027	.0264	.073	.0714	.119	.1164	.165	.1614	.211	.2064
.028	.0274	.074	.0724	.120	..1174	.166	.1624	.212	.2074
.029	.0284	.075	.0734	.121	.1184	.167	.1634	.213	.2083
.030	.0294	.076	.0743	.122	.1193	.168	.1643	.214	.2093
.031	.0303	.077	.0753	.123	.1203	.169	.1653	.215	.2103
.032	.0313	.078	.0763	.124	.1213	.170	.1663	.216	.2113
.033	.0323	.079	.0773	.125	.1223	.171	.1673	.217	.2123
.034	.0333	.080	.0783	.126	.1233	.172	.1682	.218	.2132
.035	.0342	.081	.0792	.127	.1242	.173	.1692	.219	.2142
.036	.0352	.082	.0802	.128	.1252	.174	.1702	.220	.2152
.037	.0362	.083	.0812	.129	.1262	.175	.1712	.221	.2162
.038	.0372	.084	.0822	.130	.1272	.176	.1722	.222	.2171
.039	.0382	.085	.0831	.131	.1281	.177	.1731	.223	.2181
.040	.0391	.086	.0841	.132	.1291	.178	.1741	.224	.2191
.041	.0401	.087	.0851	.133	.1301	.179	.1751	.225	.2201
.042	.0411	.088	.0861	.134	.1311	.180	.1761	.226	.2211
.043	.0421	.089	.0871	.135	.1321	.181	.1771	.227	.2220
.044	.0430	.090	.0880	.136	.1330	.182	.1780	.228	.2230
.045	.0440	.091	.0890	.137	.1340	.183	.1790	.229	.2240
.046	.0450	.092	.0900	.138	.1350	.184	.1800	.230	.2250

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CORRECTED DEPTH OF DOVETAIL FORM TOOLS

.231 TO .500

A	B	A	B	A	B	A	B	A	B
.231	.2260	.285	.2788	.339	.3316	.393	.3844	.447	.4372
.232	.2270	.286	.2798	.340	.3326	.394	.3854	.448	.4382
.233	.2279	.287	.2807	.341	.3335	.395	.3864	.449	.4392
.234	..2289	.288	.2817	.342	.3345	.396	.3873	.450	.4402
.235	.2299	.289	.2827	.343	.3355	.397	.3883	.451	.4411
.236	.2308	.290	.2837	.344	.3365	.398	.3893	.452	.4421
.237	.2318	.291	.2846	.345	.3375	.399	.3903	.453	.4431
.238	.2328	.292	.2856	.346	.3384	.400	.3913	.454	.4441
.239	.2338	.293	.2866	.347	.3394	.401	.3922	.455	.4451
.240	.2348	.294	.2876	.348	.3404	.402	.3932	.456	.4460
.241	.2357	.295	.2886	.349	.3414	.403	.3942	.457	.4470
.242	.2367	.296	.2895	.350	.3424	.404	.3952	.458	.4480
.243	.2377	.297	.2905	.351	.3433	.405	.3962	.459	.4490
.244	.2387	.298	.2915	.352	.3443	.406	.3971	.460	.4499
.245	.2396	.299	.2925	.353	.3453	.407	.3981	.461	.4509
.246	.2406	.300	.2934	.354	.3463	.408	.3991	.462	.4519
.247	.2416	.301	.2944	.355	.3472	.409	.4001	.463	.4529
.248	.2426	.302	.2954	.356	.3482	.410	.4010	.464	.4539
.249	.2436	.303	.2964	.357	.3492	.411	.4020	.465	.4548
.250	.2445	.304	.2974	.358	.3502	.412	.4030	.466	.4558
.251	.2455	.305	.2983	.359	.3512	.413	.4040	.467	.4568
.252	.2465	.306	.2993	.360	.3521	.414	.4050	.468	.4578
.253	.2475	.307	.3003	.361	.3531	.415	.4059	.469	.4588
.254	.2485	.308	.3013	.362	.3541	.416	.4069	.470	.4597
.255	.2494	.309	.3022	.363	.3551	.417	.4079	.471	.4607
.256	.2504	.310	.3032	.364	.3560	.418	.4089	.472	.4617
.257	.2514	.311	.3042	.365	.3570	.419	.4098	.473	.4627
.258	.2524	.312	.3052	.366	.3580	.420	.4108	.474	.4636
.259	.2533	.313	.3062	.367	.3590	.421	.4118	.475	.4646
.260	.2543	.314	.3071	.368	.3600	.422	.4128	.476	.4656
.261	.2553	.315	.3081	.369	.3609	.423	.4138	.477	.4666
.262	.2563	.316	.3091	.370	.3619	.424	.4147	.478	.4676
.263	.2573	.317	.3101	.371	.3629	.425	.4157	.479	.4685
.264	.2582	.318	.3111	.372	.3639	.426	.4167	.480	.4695
.265	.2592	.319	.3120	.373	.3648	.427	.4177	.481	.4705
.266	.2602	.320	.3130	.374	.3658	.428	.4186	.482	.4715
.267	.2612	.321	.3140	.375	.3668	.429	.4196	.483	.4724
.268	.2621	.322	.3150	.376	.3678	.430	.4206	.484	.4734
.269	.2631	.323	.3159	.377	.3688	.431	.4216	.485	.4744
.270	.2641	.324	.3169	.378	.3697	.432	.4226	.486	.4754
.271	.2651	.325	.3179	.379	.3707	.433	.4235	.487	.4764
.272	.2661	.326	.3189	.380	.3717	.434	.4245	.488	.4773
.273	.2670	.327	.3199	.381	.3727	.435	.4255	.489	.4783
.274	.2680	.328	.3208	.382	.3737	.436	.4265	.490	.4793
.275	.2690	.329	.3218	.383	.3746	.437	.4275	.491	.4803
.276	.2700	.330	.3228	.384	.3756	.438	.4284	.492	.4812
.277	.2709	.331	.3238	.385	.3766	.439	.4294	.493	.4822
.278	.2719	.332	.3247	.386	.3776	.440	.4304	.494	.4832
.279	.2729	.333	.3257	.387	.3785	.441	.4314	.495	.4842
.280	.2739	.334	.3267	.388	.3795	.442	.4323	.496	.4852
.281	.2749	.335	.3277	.389	.3805	.443	.4333	.497	.4861
.282	.2758	.336	.3287	.390	.3815	.444	.4343	.498	.4871
.283	.2768	.337	.3296	.391	.3825	.445	.4353	.499	.4881
.284	.2778	.338	.3306	.392	.3834	.446	.4363	.500	.4891

Contributed by A. M. Smith, Packard Motor Car Co.

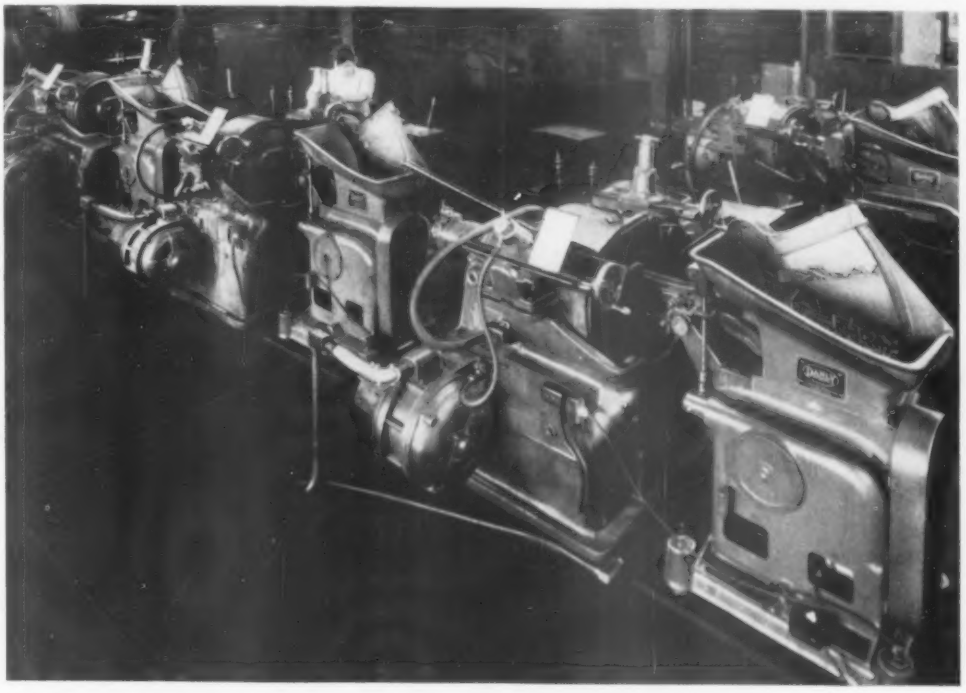
ARE YOU MAKING THE MOST OF GRINDING?

By F. M. GERTISER

Developments take place so rapidly that they often may come about unheralded and unnoticed. Even then, they may exist a considerable while before their true significance is appreciated. This is exactly what has occurred with grinding.

To many, grinding means merely the machining of various metallic or non-metallic parts to precision limits. To production managers in machine shops, however, grinding is considered a necessary and vital operation in accurate, low-cost manufacturing. Today, grinding means greater precision than ever, it represents the quickest way to accomplishing certain objectives, affords the lowest cost methods that short-circuit additional set-ups and operations. Because of these very worthwhile advantages of grinding, precision machining operations such as grinding have made immense strides in the last few years. When the opportunities and possibilities of grinding are more widely appreciated, there is every reason to believe that this valuable method of removing metal and other materials will be more widely used and more intensively applied.

At first the grinding machine was a rather lightly constructed unit in which the vibration of the machine itself and the centrifugal force of the wheel determined the capacity for work as well as the accuracy of performance. The first cost was high and the power of the machine was low. Today, however, grinding machines are strong, sturdy, and heavy. They are equipped with motors four or five times more powerful than those formerly used, thus increasing the capacity for work. Vibration and friction loss has been minimized by the use of anti-friction bearings so that the overall mechanical efficiency is higher, while deeper cuts are possible without vibration and chatter. Consequently the



Battery of Three Cincinnati Centerless Grinders, Operating in Series on Strictly Straight-Line Production, Each Grinder Served by an Automatic Hopper-Feed, One Man Operating All Three Machines.

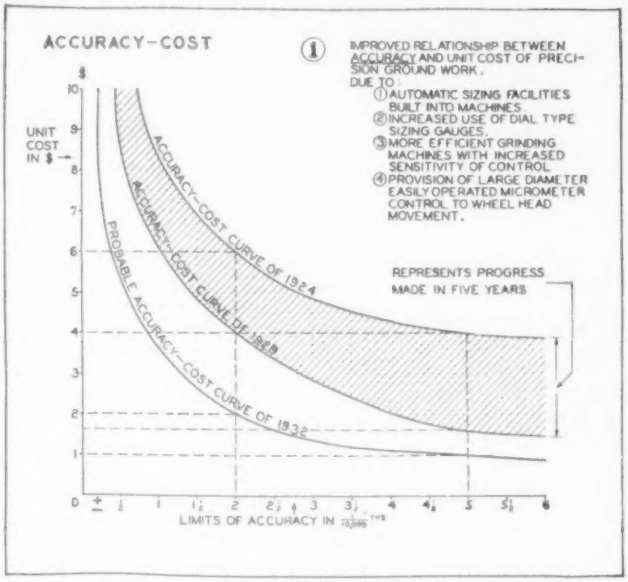

ACCURACY–COST
IMPROVED RELATIONSHIP BETWEEN ACCURACY AND UNIT COST OF PRECISION GROUND WORK.
DUE TO:
①AUTOMATIC SIZING FACILITIES BUILT INTO MACHINES.
②INCREASED USE OF DIAL TYPE SIZING GAUGES.
③MORE EFFICIENT GRINDING MACHINES WITH INCREASED SENSITIVITY OF CONTROL.
④PROVISION OF LARGE DIAMETER EASILY OPERATED MICROMETER CONTROL TO WHEEL HEAD MOVEMENT.
UNIT COST IN $
ACCURACY–COST CURVE OF 1924
ACCURACY–COST CURVE OF 1929
PROBABLE ACCURACY–COST CURVE OF 1932
REPRESENTS PROGRESS MADE IN FIVE YEARS
LIMITS OF ACCURACY IN

Fig. 2—Curve showing relationship between accuracy and unit cost of precision ground work.

field for grinding has been greatly changed.

Men of the "old school" often look upon grinding as a precision operation calling for delicate adjustment, a costly operation to be performed only when no other method was possible. Today, the tendency is towards greater precision and thus grinding plays an important in the finishing of cylindrical work,

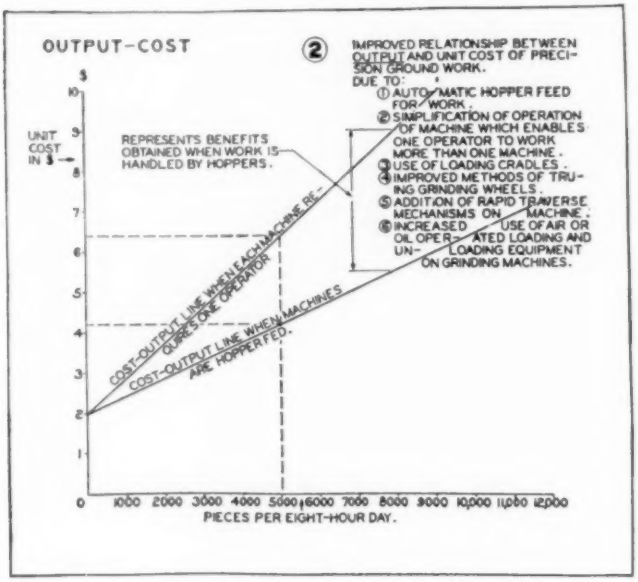

OUTPUT-COST
②
IMPROVED RELATIONSHIP BETWEEN OUTPUT AND UNIT COST OF PRECISION GROUND WORK.
DUE TO:
① AUTOMATIC HOPPER FEED FOR WORK.
② SIMPLIFICATION OF OPERATION OF MACHINE WHICH ENABLES ONE OPERATOR TO WORK MORE THAN ONE MACHINE.
③ USE OF LOADING CRADLES.
④ IMPROVED METHODS OF TRUING GRINDING WHEELS.
⑤ ADDITION OF RAPID TRAVERSE MECHANISMS ON MACHINE.
⑥ INCREASED USE OF AIR OR OIL OPERATED LOADING AND UNLOADING EQUIPMENT ON GRINDING MACHINES.
UNIT COST IN $
REPRESENTS BENEFITS OBTAINED WHEN WORK IS HANDLED BY HOPPERS.
COST-OUTPUT LINE WHEN EACH MACHINE REQUIRES ONE OPERATOR
COST-OUTPUT LINE WHEN MACHINES ARE HOPPER FED.
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10,000 11,000 12,000
PIECES PER EIGHT-HOUR DAY.

Fig.3—Improved relationship between output and unit cost of Precision Ground work shown graphically.

especially where accuracy is desirable or indispensable. By applying ample power to modern grinding machines, it is possible to remove metal quickly. With a modern precision cylindrical grinder of either the centerless or the controlled center type, the following rates of metal removal can be accomplished in a commercially attractive way:

Horsepower applied to grinding wheel spindle.	Metal removal capacity, cubic inches per minute, cast-iron or steel.
5	½
10	1
15	1½
20	2
25	2½
30	3
35	3½
40	4

It can be seen, therefore, that modern grinding machines not only accomplish their purpose of imparting extreme accuracy to work, but do it quickly by removing metal quickly.

The rapid development and refinements in the art of grinding have exerted a tremendous influence on the manufacturing costs of hundreds of commodities in daily use, so that grinding is now looked upon as one of the most important machine shop operations of today.

In the past few years refinements in design, improvements in abrasives and new developments have done much to reduce costs, improve accuracy, and increase production. Reference to the three accompanying diagrams pictorially illustrates just what advance has been made. These charts have been prepared by Mr. R. E. W. Harrison, Secretary, Machine Shop Practice Division, The American Society of Mechanical Engineers.

Mass production, for example, has enabled manufacturers to obtain a lower unit production cost. One of the outstanding contributions made within the past 1½ years is the automatic hopper. This development represents one of the greatest advances in the progressive increase of output per operator since the advent of the centerless grinder itself. By employing these hoppers in conjunction with centerless grinders, manual feeding operations are reduced, fatigue is lessened for the operator, and one man can operate a battery of three, four, or more machines, thus reducing costs 25% to 40%. The operator fills the first hopper basin (see illustration) and all succeeding operations are automatic.

Reports received from users of these modern tools, emphasize the cost-reducing and accuracy-improving results which manufacturers are obtaining on new grinding machines. Typical performance is as follows:

A prominent mid-western railroad reports a saving of $200.00 on each crankshaft which is now ground on a modern cylindrical grinder; the line and pin bearings were formerly machined on a lathe. In addition, of course, the bearings are more accurate in size and alignment.

In New York a manufacturer is grinding driving rolls in 7½ minutes on a modern centerless grinder

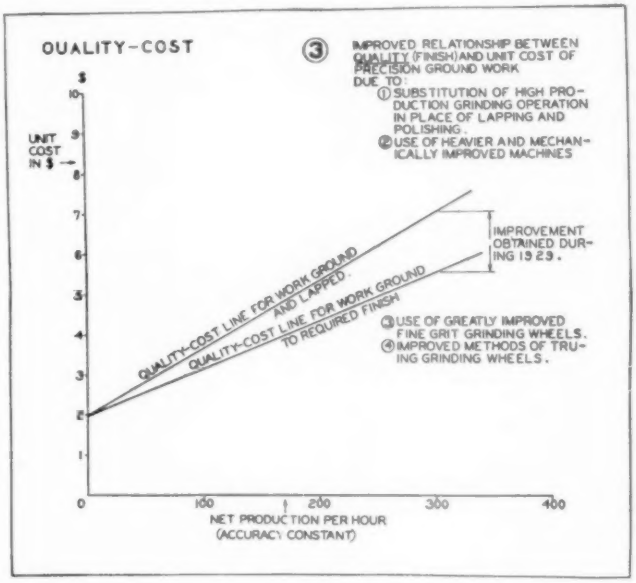

QUALITY-COST
③
IMPROVED RELATIONSHIP BETWEEN QUALITY (FINISH) AND UNIT COST OF PRECISION GROUND WORK
DUE TO:
① SUBSTITUTION OF HIGH PRODUCTION GRINDING OPERATION IN PLACE OF LAPPING AND POLISHING.
② USE OF HEAVIER AND MECHANICALLY IMPROVED MACHINES
UNIT COST IN $
IMPROVEMENT OBTAINED DURING 1929.
QUALITY-COST LINE FOR WORK GROUND AND LAPPED.
QUALITY-COST LINE FOR WORK GROUND TO REQUIRED FINISH
③ USE OF GREATLY IMPROVED FINE GRIT GRINDING WHEELS.
④ IMPROVED METHODS OF TRUING GRINDING WHEELS.
0 100 200 300 400
NET PRODUCTION PER HOUR (ACCURACY CONSTANT)

Fig. 4—Relationship between quality of finish and unit cost between precision ground work and work that is ground and lapped.

whereas it formerly required 30 minutes on an old style machine.

A Chicago manufacturer reports a 100% production increase by grinding shafts on a new cylindrical grinder.

A prominent pen and pencil company is getting a net return on investment of more than 100%. The grinder upon which parts are furnished will pay for itself in less than a year.

One of the large electrical manufacturers reports that due to the installation of modern grinding machines, the company was able to accept orders on lots of motors at a profit whereas if these machines had not been available, it would have been impossible to accept the orders at a profit.

Those who think of grinding in terms of 10 or even 5 years ago should "re-discover" it. Though the surface of this subject has barely been scratched in the above, enough has been said to show that grinding offers very great and usually unappreciated opportunities to cut costs, minimize operations and save time. Very great savings are often possible by employing grinding. Are you missing an opportunity?

TIME AND MOTION STUDY

By O. B. JONES*

Philanthropists may preach to business men the doctrine that inefficient manufacturing methods should be enforced in order that all men may work and thus be given the right to earn money with which to buy the products of their labor, but—they will never succeed in convincing the engineer or the multitude of shareholders of the corporations that there can ever be any justification for waste. Waste is a weapon—not a tool. When the race gets to the point where wasteful employment of labor is resorted to as a means of wealth distribution, the race will soon have no wealth to distribute.

It seems to us now that the time will never come when we can use any natural resource unless or until man has labored to release it and put it into a usable state, by virtue of which labor it becomes wealth. It may be true also that the labor of man provides a practical means of distributing wealth, just as his labor results in its creation, but we must be careful not to confuse mental labor with physical labor.

Physical labor may be destined to disappear from the face of the earth. It does not belong to civilization. But when this time arrives, the mind of man will still be required to direct the forces of nature to do the physical work needed for the preservation and pleasure of the race. In fact, this condition exists now to a much greater extent than is appreciated by the average person. It is estimated that less than five per cent of the power used in industry today is contributed by the muscle of man. Fossil fuels dug from mines, potential energy released in waterfalls, and other forms of energy stored on earth in lavish superabundance turn ninety-five per cent of all the wheels of industry today and constitute the potential wealth of man.

FUNCTION OF TIME AND MOTION STUDY

The tool engineer is employed by manufacturers to remove the five per cent of man power now being used as horsepower, and also to make the efforts of all workers more efficient in the creation of wealth, whether they be hand workers or head workers or combinations of the two. The principles governing the efficient application of human effort in industry are grouped under the head of time and motion study.

When the factory worker first saw someone with a watch in his hand peering at him from behind a post he was very naturally suspicious and somewhat indignant. One of the things he suspected was that he was to be reported to the boss who would probably fire him for not putting forth as much physical exertion as his employer felt was his due. However, this condition did not exist for long, for the time study man soon discovered that the cooperation of the worker was needed in order that an accurate time for doing the job could be determined. He was thus forced to tell the worker what it was all about, and discovered to his delight and surprise that the worker was sufficiently intelligent to appreciate that time study was as much a benefit to him as to his employer.

The day rate plan of payment was never satisfactory to the intelligent worker. Time study became a necessity when the plan of paying a worker according to the number of pieces produced was adopted. The operation consists simply of timing a worker and counting the number of pieces produced in that time. If the time is one hour, the hourly rate of pay one dollar, and the number of pieces produced is one hundred, then the piece work rate is one cent a piece. As simple as that may seem, when the system was first adopted there was a constant battle between the management on the one side and the man on the other, because of the greed and suspicions of each. Eventually the worker and the employer worked out a scheme which functions about as well as any system which depends for its success upon human understanding and involves the most elemental brute instincts of human nature.

The one great advantage of the system is that the employee feels that he is being properly rewarded for his investment of time, energy, intelligence, and effort, while the employer feels that his investment

* Detroit College of Applied Science.

of money in plant and equipment is returning to him all that he has a right to expect—under the circumstances. Instead of capital and labor playing the roles of wolves fighting over the spoils of battle, the worker feels that he is in business for himself and that it is up to him to make the equipment under his care produce to the maximum if his personal profits are to be the greatest possible. (Does it not remind you of the birds that you have seen in the movies riding on the back of a rhinoceros, and earning their living by that precarious ride? The birds exist by eating the insects which would otherwise injure the health of the rhinoceros. Both benefit.) The worker becomes a business man in partnership with the man or corporation which rents him the equipment he operates.

DETERMINATION OF STANDARD OPERATION TIMES

One of the greatest difficulties encountered in arriving at the standard time required to perform an operation is the difficulty of finding the "average man." If a hundred men perform the same operation there is such a spread in the time required by each man that if the average of all their times is found, and the piece work rate is based on this average time, then the man much below the average cannot make a satisfactory wage and the man above the average receives an amount out of all proportion to his real investment.

It did not take the time study man long to see the necessity for making a minute study of the various methods used by different men in doing their work, in order that the best method might be the method used by all. Naturally, when he was confronted with the fact that labor turnover resulted from this difference in the method of doing things, he began to study the motions of the operators to determine the reason for the variations in the time required.

When the one best way of performing any task is found, it is invariably the way that permits the operator's hands to move the least distance, or to change direction the least number of times, or in short, it is the way that calls for the least physical exertion—the simplest motions, and the least number of them.

The late Frank P. Gilbreth and Lillian M. Gilbreth seem to have been the pioneers in formulating the principles of motion study. Frank Gilbreth's actions were impelled by the motive indicated in his statement, 'There is no waste of any kind in the world that equals the waste from needless, ill-directed, and inefficient motions, and the resulting unnecessary fatigue."

In his first studies he attached a lighted electric light bulb to the hand of the operator and recorded the motion of the hand as a path of light on a camera film, the lens of the camera having been left open during the complete movement. From the film he made up a wire model which indicated the path traveled through by the hand. His stop watch told him the total time required for the whole motion, but because of the speed of the average motion, he could not tell the time required for each of the elemental motions, which in the aggregate constituted the entire motion. That is, he knew the elapsed time from end of the wire model to the other, but did not know the time from one bend to the next.

In his later experiments Gilbreth used a slow motion picture comera and always had a special clock in the pictuce (Fig. 3) so that he could record the

THERBLIG CHART

NAME OF THERBLIG	SYMBOL	EXPLANATION SYMBOL SUGGESTED BY	COLOR
Search		Roving Eye as if Searching	Black
Find		Eye Fixed on Object	Dark Gray
Select		Reaching for Object	Light Gray
Grasp		Hand Open for Grasping	Lake Red
Transport Loaded		Hand With Something in It	Dark Green
Position		Object Being Placed By Hand	Dark Blue
Assemble	#	Several Things Put Together	Dark Violet
Use	U	First Letter-Word "Use"	Purple
Dis-Assemble	#	One Part of Assembly Removed	Light Violet
Inspect		Magnifying Lens	Burnt Ochre
Pre-Position		A Ten-Pin	Sky Blue
Release Load		Dropping Content from Hand	Carmine Red
Transport Empty		Empty Hand	Olive Green
Rest to Overcome Fatigue		Man Seated as if Resting	Orange
Unavoidable Delay		Man Stumbling-Unintentional	Yellow Ochre
Avoidable Delay		Man Lying Down on Job	Lemon Yellow
Plan		Man-Hand at Brow-Thinking	Brown

Fig. 1. Therblig chart. (Courtesy McGraw-Hill Book Co.)

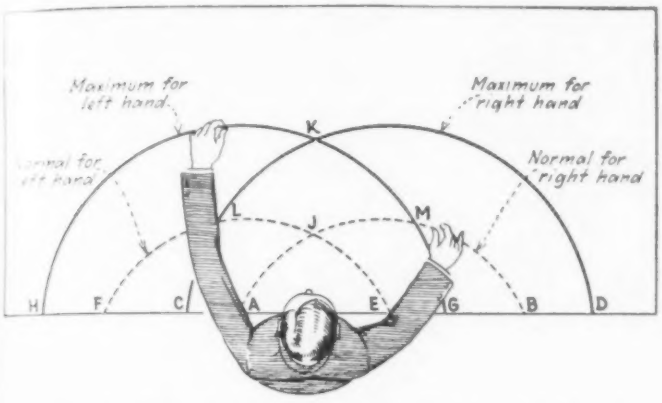


Fig. 2. Normal and maximum working areas for hands in the horizontal plane. (Courtesy McGraw-Hill Book Co.)

motion and the time simultaneously. At the present time, pictures are taken at the rate of one thousand each minute, and the time is measured in units of one two-thousandths of a minute. Gilbreth called this unit of time a "wink." A Japanese engineer has perfected a camera which take several hundred pictures (frames) a second, and time is being recorded in units of a millionth part of an hour.

One might well ask, "Why all the refinement in time measurement, when humans are so un-standard?" The answer is simple. The value of one hundredth of a minute at seventy-five cents an hour, over the period a three-hundred day year, on a production of ten thousand pieces a day, with the average two hundred per cent of overhead added, is $1140. Perhaps King Solomon, in his wisdom, was thinking of this when he said, "It's the *little* foxes that spoil the vines!" By a minute study of motions it is possible to standardize them and thus bring about enormous savings.

FUNDAMENTAL MOVEMENTS

Gilbreth analyzed the motions of workers in several industries, and was able to build up synthetically any and all of the motions of workers performing any and all operations from seventeen fundamental motions which he called therbligs. The name therblig is obtained by spelling the name Gilbreth backwards, approximately. He named them as follows: search, find, select, grasp, transport loaded, position, assemble, use, dis-assemble, inspect, pre-position, release load, transport empty, rest for overcoming fatigue, unavoidable delay, avoidable delay, and plan. If one keeps in mind an operator of a drill press, and in his mind's eye sees him going through the cycle of operations, he will clearly see the significance of the names. All the motions before the word "use" are the acts required to get the part into position to drill. The word "use" in this illustration indicates the operation of drilling.

The chart in Fig. 1 (which is reproduced here by courtesy of the McGraw-Hill Book Company, from the book, "Time and Motion Study," by Lowry, Maynard, and Stegemerten) lists the seventeen therbligs with their symbols and explanation of how the symbols originated. Gilbreth divided the seventeen motions into five groups according to the location of the muscles producing them, as follows:

1. Finger motions only
2. Combination finger and wrist motions
3. Combination finger, wrist, and forearm motions
4. All arm motions from shoulder to tips of fingers
5. A combined movement consisting of all the above, and also body motions.

Work should be planned, fixtures, and tools designed, and the work-place arranged to avoid the use of the higher numbered groups wherever possible.

Fig. 2 shows the areas over which the hands can be used without excessive and fatiguing body movements. Fig. 3 is a photograph of a proper arrangement of tools and parts. Each article is kept in a specific place in the inclined tray. The tray is arranged like an ampitheatre so that the motion of picking up can be a straight line motion, which would not be the case if the operator had to dip into the tray. The skilled operator can find all parts while her eyes are resting or being used to better advantage—exactly the principle used in the efficient keyboard arrangement of the typewriter.

Fig. 3. Proper arrangement of work area. (Courtesy McGraw-Hill Book Co.)

PRINCIPLES OF MOTION STUDY

1. Both hands should preferably begin their therbligs simultaneously.
2. Both hands should preferably complete their therbligs at the same instant.
3. Both hands should not be idle at the same instant except during rest periods.
4. Motions of arms should be in opposite and symmetrical directions, instead of in the same direction, and should be made simultaneously.
5. Hesitation should be analyzed and studied, its causes accounted for and if possible eliminated.
6. Shortest time demonstrated in one part of a study should be used as a mark to attain, and reason for other times required in other parts of the study should be known.
7. Number of therbligs required to do work should be counted; for the best way is almost always a sequence of the fewest therbligs.
8. The best sequence of therbligs in any one kind of work is useful as suggesting the best sequence in other kinds of work.
9. Every instance where delay occurs suggests advisability of providing some optional work that will permit utilizing the time of delay, if so desired, or of making fatigue study of the interval.
10. Variations of time required for any single therblig should be arrayed and causes recorded.
11. Lateness of various parts of the anatomy as compared with other portions should be recorded.
12. All material and tools should be located within the normal grasp area.
13. Motions should be confined to lowest possible classifications in order to reduce fatigue, as listed below giving the least fatigue and most economical first.
    - 1st. Finger motions
    - 2nd. Finger and wrist motions
    - 3rd. Finger, wrist, and lower arm motions
    - 4th. Finger, wrist, lower arm and upper arm motions
    - 5th. Finger, wrist, lower arm, upper arm and body motions.
14. Tools and materials should be located as to permit proper sequence of therbligs. The part required at the beginning of the cycle should be next to the point of release of the finished piece from the former cycle.

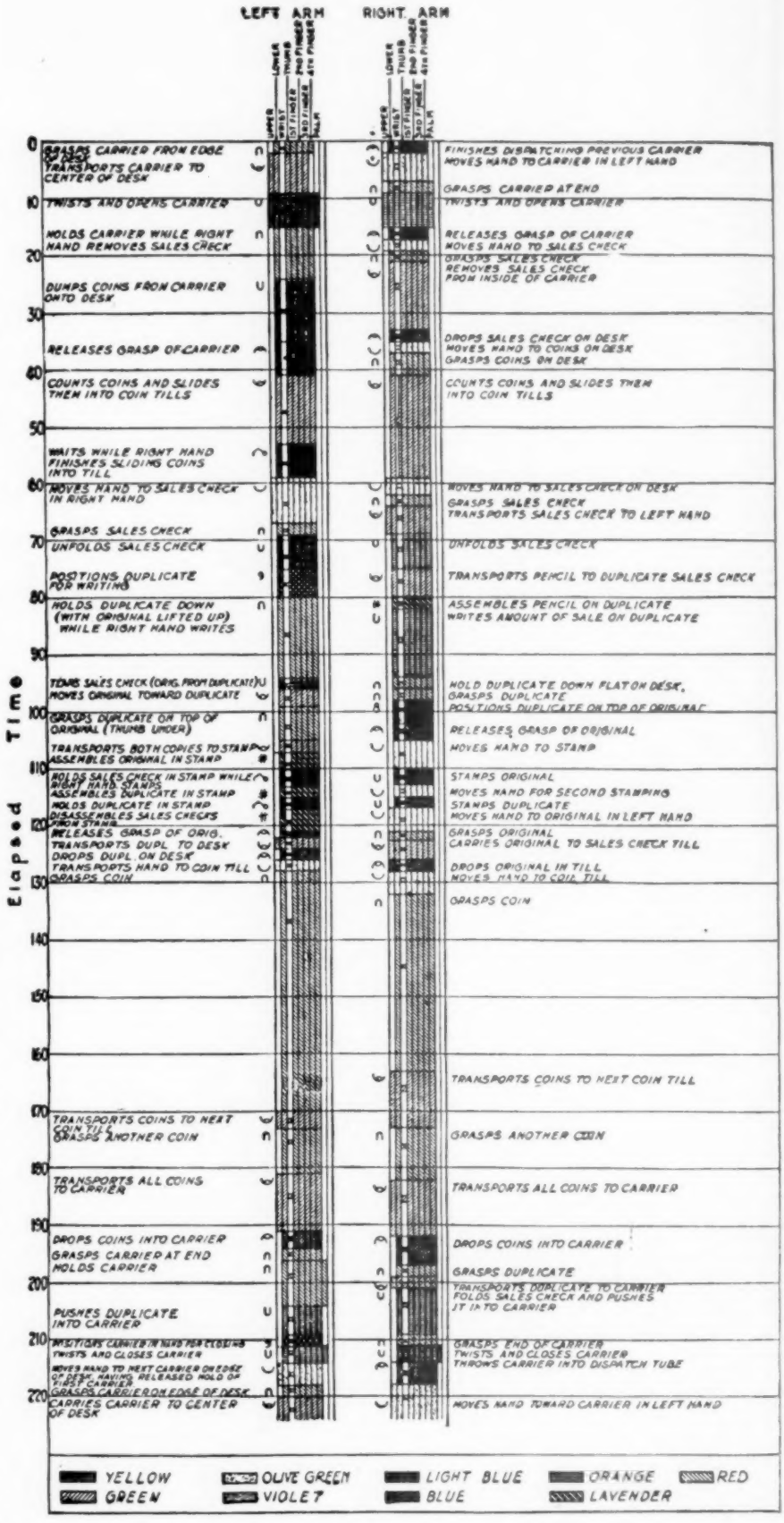


Fig. 4. Simultaneous motion cycle chart. (Courtesy McGraw-Hill Book Co.)

15. Sequence of motions should be arranged to build rhythm and automaticity into the operation.
16. Hands should be relieved of all work that can be done by feet or other parts of the body.
17. Tools and materials should be pre-positioned as much as possible to reduce the *search*, *find* and *select* therbligs.
18. Gravity feed containers should be used to deliver the material as close to the point of assembly o ruse as possible. This delivery point should be near the height at which it is assembled in order to eliminate any lifting or change in direction in carrying the parts to the assembly.
19. Ejectors should be used to remove the finished part.
20. Use "drop delivery" whereby the operator may deliver the finished article, by releasing it in position in which it was completed, without moving to dispose of it.

PRACTICAL RESULTS OF TIME AND MOTION STUDY

Due to the refinement of the technique of motion study it is now possible to standardize the motions of the operator of any machine so that they will consist of the least number, performed in the most efficient order. With the knowledge now available the pre-determination of labor costs is becoming an exact science. Standard times for the fundamental motions are being determined more exactly each week. Soon reliable tables of standard times will be available for the cost estimator and tool engineer—and two or three per cent of the remaining five per cent of human-muscle labor now being expended in industry will be wiped out—and we'll all have to play more golf to keep the next generation from being born armless and legless—if it is born at all!

A time study cannot be made correctly without being preceded by motion study. The procedure varies in different industries, and in different plants in the same industry, because of the newness of the art and the differences in the equipment available for the purpose. The following brief outline pictures the average procedure followed in making a time and motion study with nothing more elaborate than a stop watch, a speed indicator, and a note pad.

As stated previously, one object of time and motion study is to determine the correct amount of time required to perform an operation. The correct time may not always be the least time, but should be considered as the least reasonable time or the least workable time. An operation is the cycle of motions made by the operator from the time the work is picked up until the job is completed and released ready to pick up another piece at the beginning of the next cycle. The complete cycle of movements is broken up into sub-operations and the time for each sub-operation found by means of a stop watch. Unnecessary movements can be observed and eliminated, and feeds and speeds of machines checked, poor design of clamps on fixtures corrected, and unnecessarily long times on necessary movements corrected. One important element of time study is the finding of the maximum capacity of the machine and tools, and then to so order the speeds and feeds that the proper balance is struck between the time saved by speeding up the machine and the increased tool cost or poor finish on the work.

The human element should be considered carefully in making time and motion studies. Fatigue, "off" days, weather, and many other variable conditions should be neutralized as much as possible by making the studies at various hours of the day or days of the week. The time set up as the standard time is not the average time, but between the average time and the minimum time, and it is so set up because of its effect upon the bonus earned by the worker.

The following table (Fig. 5) contains the results of an actual study, and is shown because it illustrates the average variation in times and how the operation is broken down into sub-operations. The operation was the drilling of one $\frac{7}{32}$" hole on a twenty-inch power-feed drill press with a feed of 0.010". Under the headings 1, 2, 3, ... 8, the time in minutes is recorded for each sub-operation.

Sub-operation	1	2	3	4	5	6	7	8	Standard
Clean jig	.10	.11	.09	.10	.11	.12	.10	.09	.09
Clamp piece	.21	.16	.17	.13	.18	.18	.22	.18	.15
Drill	1.10	1.12	1.13	1.10	1.12	1.13	1.13	1.13	1.11
Remove piece	.07	.12	.13	.14	.13	.07	.09	.06	.07

Fig. 5. Time study sheet

MICRO-MOTION STUDY

In the example just cited no attention was given to elemental motions, that is, to therbligs. The first sub-operation, clean jig, evidently consisted of a combination of lesser fundamental motions or therbligs. Now certainly, there are many ways of cleaning a jig, even if the same apparatus is used for cleaning it. There are many opportunities for lazy thinkers to form wrong habits which are wasteful of time, because they do not, and perhaps cannot, properly analyze their motions so that the ideal result can be accomplished in a minimum of time. One operator will labor twice as long to perform such a sub-operation as his partner on a similar operation, and at the conclusion of the task be more fatigued and not have the locaters as free of chips as his physically lazy and therefore mentally alert partner's.

In breaking up the sub-operations into therbligs, a micro-motion study is made by use of the camera and clock described above. Several motion pictures are taken of each cycle of operations. The pictures are then projected on a screen, where they are slowed down or brought to a complete stop in order that the reviewer can study each motion to determine whether it is in conformity with the fundamental laws of motion economy. With the clock in the picture it is possible to determine the time required for making each elemental motion.

Each therblig of the left hand is recorded in an upright column opposite the therblig of the right hand being performed at the same time. The chart in Fig. 4 is one of the many types used. Note that each finger of each hand is accounted for. This, of course, would be impracticable without the use of the camera.

After the chart is made up showing the old method of doing the job, a new chart is built up synthetically showing a new way which more completely conforms to the laws of motion economy. The operator is instructed in the new way until he becomes thoroughly proficient in its use. If other operators are to be trained in the performance of the same operation, a film is taken of the experienced operator as he performs the operation in the improved manner, and this film is projected and explained to the operator who is to be trained.

Where studies have been made in this manner great savings in time have been effected.

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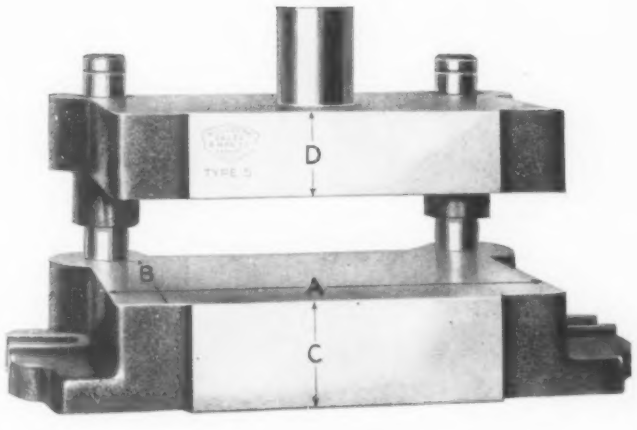

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